Tracking the Global Spread of Advanced Technologies

The Center for Global Security Research is examining how new technologies in the wrong hands could threaten national security.

GIVEN the pace of technological advancements and their rapid diffusion to the far corners of Earth, what might the world look like in 15 to 20 years? And what are the implications for America's national security and for its deterrence options? To answer those questions, Lawrence Livermore's Center for Global Security Research (CGSR) is sponsoring workshops involving some of the brightest minds in science and technology, government, and academia.

"Technology is spreading incredibly fast, and breakthroughs do not respect national borders," says geophysicist Eileen Vergino, CGSR deputy director. "We want to examine the national security risk from the spread of new

Vice Admiral Arthur Cebrowsi, president of the Naval War College, and George Shultz, former Secretary of State and currently a fellow at Stanford University's Hoover Institution, discuss national security threats posed by the globalization of advanced technologies.

technologies and decide if there are particular threats that the nation ought to be focusing on." She explains that the CGSR workshops have not concentrated on response options to immediate threats; rather, they have focused on the more distant future 15 to 20 years away. (See box on p. 14.)

Vergino notes that as global tensions have relaxed, so have restrictions on the flow of commercial and military technologies. Military forces, including this nation's, are turning to commercial electronic components to take advantage of industry's rapid innovations and to hold down costs. Adversaries, too, have access to many of the same technologies that the U.S. relies on for conventional warfare, and therein lies one threat considered in CGSR workshops.

Last year, CGSR brought together different groups of experts to discuss likely technology-driven threats to the U.S. and its allies in the 2015 to 2020 timeframe. The series of workshops was entitled "After Globalization: Future Security in a Technology-Rich World." About 100 participants gathered from other national laboratories, the Department of Defense, the National Aeronautics and Space Administration, Congress, the intelligence community, universities, think tanks, consulting firms, and private industry. In addition, about 40 Livermore scientists, with backgrounds ranging from molecular biology to global climate change, participated.

Participants at each workshop were asked to examine threats from nuclear, missile, and space technology; conventional military technology; information technology; biological technology; or geological systems technology. In December 2000, an Integration Workshop and Senior Review involving national leaders and experts was held to discuss the workshops' findings. A top-flight panel was led by former Secretary of State George Shultz, who was introduced by CGSR director Ron Lehman as the "father of globalization."

Spotting Troublesome Innovations

The "After Globalization" workshops were conceived and sponsored by CGSR Director Lehman and led by Livermore engineer and CGSR senior fellow Thomas Gilmartin. "The workshops focused on what we know, what we do not know or cannot agree on, and what is needed to resolve the unknowns," says Gilmartin. "We took into account historic threats but emphasized potentially troublesome innovations in every technology area."

Gilmartin says that developing threat responses was outside the project's scope but might be the goal of follow-on projects. "We set this limit because a focus on response would limit the time and energy that participants spent on imagining a full range of possible threats. The discussion of threats and enabling technologies alone is a prodigious task."

Participants noted that the Internet, migration, multinational corporations, and global research collaborations are all helping to give every nation as well as small extremist groups access to resources and technical knowledge. Participants also pointed to the importance of so-called dual-use technologies. For example, the same computer workstation used ostensibly for animation could be used for designing a nuclear warhead. Medical equipment supposedly purchased for making pharmaceuticals could be used instead to produce new strains of infectious microbes.

Much discussion focused on the globalization and proliferation of nuclear weapons as well as technologies that could sharply affect the cost of nuclear weapon development, production, and delivery. Such technologies include computers, nuclear materials enrichment, robotics, machining, cruise missiles, space launch vehicles, global positioning systems, and satellite imaging.

At the same time, advanced technologies for nonnuclear weapons are diffusing rapidly throughout the globe. The net effect is to provide future enemies with access to advanced equipment and technologies such as remotely guided weapons and stealth technologies—or at least the know-how to develop them. U.S. air and sea operations may thereby face smart

A number of threat sources, ranging from terrorist groups to emerging nations, are capable of accessing advanced technologies and know-how provided by corporations, the Internet, the black market, and other sources.

mines, quiet submarines, stealth planes, and advanced antiaircraft missiles.

Weapons containing advanced technologies are being manufactured and offered for sale by a growing number of nations. For example, a German propulsion frigate with stealth technology is being built for South Africa. India and other nations are developing hypersonic ramjet missiles. And Russia is marketing MIG fighter jets with state-of-the-art missiles.

Wide-Ranging Threats

In all, participants cited 45 possible threats covering a wide range of lethality and likelihood of occurrence and including more than 60 enabling technologies. Many of the threats were traditional, such as nuclear warfare. Other scenarios were more speculative—bordering on science fiction—yet quite possible in the future, given the pace of innovation and discovery.

The threats were ranked by risk, that is, the probability of their occurrence times the severity of their consequences. The top threats were judged to be nuclear weapons used in a terrorist attack; diseases, both natural and engineered; nuclear weapons used in a limited regional war; a major nuclear war; human control of future biological forms; a lessening of the dominance of U.S. conventional force; and gaining and losing control of nature. Asymmetry—taking advantage of gross differences in vulnerability, tactics, or values of one nation's military power over other nations'—and information operations were also discussed. (See box on p. 17.)

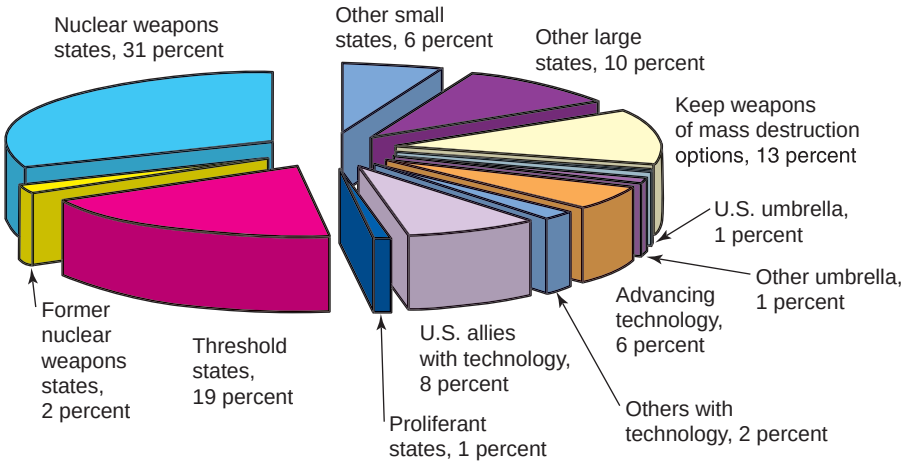
In ranking the threats, many participants felt that the potential danger of biological weapons of all types has been underestimated. Emerging and reemerging deadly diseases could be weaponized. Agricultural species could be attacked directly or infiltrated with subtle unhealthy genetic modifications to kill off a wheat crop or devastate livestock. Just the threat of such use (psycho-biological warfare) could cause fear, confusion, and poor public and governmental response.

Examples of global advanced weapon technology are evident in new generations of arms marketed by dozens of nations.

Likewise, the potential misuse of geophysical systems as weapons and threats has not received much publicity. These threats include, for example, deliberately fouling the environment with chemical poisons, flooding or desiccating areas with radioactive contaminants, disrupting natural weather cycles, destroying dams, and deliberately creating fires. Humans could even learn to start hurricanes by seeding the skies or initiate a tsunami by inducing an already weak continental shelf to slump.

The class of threats called "unintended manmade" is particularly worrisome, Gilmartin says. This class includes the consequences of global warming and the long-term results from life-form modifications, biodiversity, and habitat loss. "Such threats might start as beneficial, but humankind has proven many times to have limited foresight when exercising its stewardship of nature," he says.

In recent months, Gilmartin has presented papers on "After Globalization" at Stanford University and the University of California at Berkeley and at an international nonproliferation conference in Erice, Italy, thereby exposing an even wider international audience of scientists and policymakers to the methods and findings of these workshops.



Three of the top seven threats to U.S. national security involve nuclear weapons. The chart breaks down national nuclear weapons policy as a function of world population.

Redefining Deterrence

A new CGSR project titled "Whither Deterrence?" is examining the future of deterrence in response to the new threat scenarios. "Whither Deterrence?" consists of exploratory workshops and a concluding conference at which participants will discuss new threat scenarios, conventional and nuclear weapon systems policies, and deterrence strategies.

The first "Whither Deterrence?" workshop was held in May 2001 in Washington, D.C., drawing participants primarily from academia, military agencies, and think tanks. The second workshop was held in June at Livermore and featured experts from the national laboratories. A number of Lawrence Livermore scientists took part who are expert on nuclear and biological technologies as well as deterrence policy. A final "Whither

Center Provides Fresh Insight into National Security Issues

Founded in 1996, the Center for Global Security Research (CGSR) is an outreach effort of Lawrence Livermore National Laboratory that studies ways in which technology can enhance international security. "We probe issues at the intersection of technology and policy," says CGSR deputy director Eileen Vergino.

Vergino notes that national and international security policy is inextricably linked with technology. The center aims to help policymakers understand the limitations and capabilities of science and technology while helping scientists understand policy. "We want to bridge the gulf between the two communities," she says.

CGSR sponsors workshops, research fellows, and independent analyses. Projects typically join Lawrence Livermore scientists with other technical experts, academics, policymakers, military leaders, and industry executives. The result is fresh insight into some of the most vexing national security issues. (See *S&TR*, June 1998, pp. 10–16.)

While most projects focus on present international security concerns, other efforts such as the "After Globalization" and "Whither Deterrence?" workshops are focused beyond the next decade to help guide current U.S. actions and policy.

Vergino notes that although think tanks abound, few have such a concentration of experts in nuclear weapons, lasers, biotechnology, and other disciplines as Lawrence Livermore. CGSR, she says, is fortunate to be able to tap the expertise of Livermore scientists.

A number of well-known figures in technology and government have participated in CGSR workshops. During one CGSR event at Livermore in 1997, Attorney General Janet Reno announced the establishment of a new Federal Bureau of Investigation center to investigate attacks on the nation's critical infrastructure. Other activities have included former Secretary of State George Shultz and Secretary of Defense Donald Rumsfeld.

Deterrence?" conference is scheduled for late November at Livermore, with a panel of distinguished national leaders and experts headed by Brent Scowcroft, national security advisor to former President Bush.

Carl Poppe, physicist and CGSR fellow, is leading the workshops. "The workshops are looking at what deterrence will mean 15 to 20 years from now," he says. For example, what role will nuclear weapons play? How should we deal with the emergence of new nuclear powers or nuclear alliances? Can traditional ideas of deterrence work in the face of new kinds of weapons?

He notes that the concept of deterrence, honed during the Cold War, focused primarily on the threats posed by Soviet nuclear weapons. With seeming suddenness, the Soviet Union split apart and the world moved from bipolar (East–West) to multipolar and factional. At the same time, the spread of new technologies around the world began to accelerate.

According to Poppe, "Today there are many more ways to exploit our vulnerabilities and many more players bent on acquiring the means to do us harm. During the Cold War, we were much more focused on the potential consequences of global war than on other serious threats that could arise and require well-thought-out deterrence measures."

Poppe cites new threats such as biological and chemical weapons and computer viruses and new threat initiators such as Iran, Iraq, Libya, North Korea, and terrorist groups. One challenge is deterring the use of biological and chemical weapons when the U.S. has foresworn the use of such agents.

Analyzing Future Threats

"After Globalization" and "Whither Deterrence?" are two of several projects that target policy and technology issues of importance in the next two decades. With such projects, CGSR carries on its tradition of sponsoring efforts to analyze long-range deterrence and proliferation issues. Among these is a recent project, which concluded at a workshop in April, that focused on one particularly worrisome example of nuclear proliferation: whether the 1994 agreement with North Korea, called the "Agreed Framework," can be verified. Under this agreement, the U.S. and its

In ranking threats to the U.S., many experts believe that the destructive potential of biological weapons has been underestimated. Lawrence Livermore scientists have been developing new methods to identify biological agents that could threaten urban populations, livestock, and crops.

Evolution of Thinking on U.S. Nuclear Deterrence Policy

The U.S. policy of nuclear deterrence has evolved since the end of World War II. What role nuclear weapons will play is being debated as old threats diminish and new threats emerge.

Year	Nuclear deterrence policy
1945	World war termination; countergenocide
1947	Sole nuclear power, component-based
1954	Massive retaliation, new-look army
1963	Flexible response, escalation dominance
1965	Assured destruction; damage limiting
1967	Mutual assured destruction
1969	Sufficiency; escalation control
1974	Essential equivalence
1976	Rough equivalence
1979	Presidential Directive 59; countervailing strategy
1981	National Security Defense Directive 13; peace through strength
1983	Strategic Defense Initiative
1989	Weapons of last resort
1994	Nuclear posture review
1997	Post–Cold War deterrent with hedge
2001	Deterrence, Assurance, Dissuasion, Defense
200?	Sustained deterrent? Flexible deterrent? Responsible hedge deterrent? Minimal deterrent? Recessed deterrent? Virtual deterrent? Undeterrence?
201?	Held in trust for humans?
2???	Reconstitution as a safeguard?

allies pledged to build two nuclear power reactors in North Korea and to provide fuel-oil shipments until the reactors were built. North Korea, in exchange, agreed to declare how much material it had produced for nuclear weapons, to stop producing the material at specific facilities, and to observe the Nuclear Non-Proliferation Treaty.

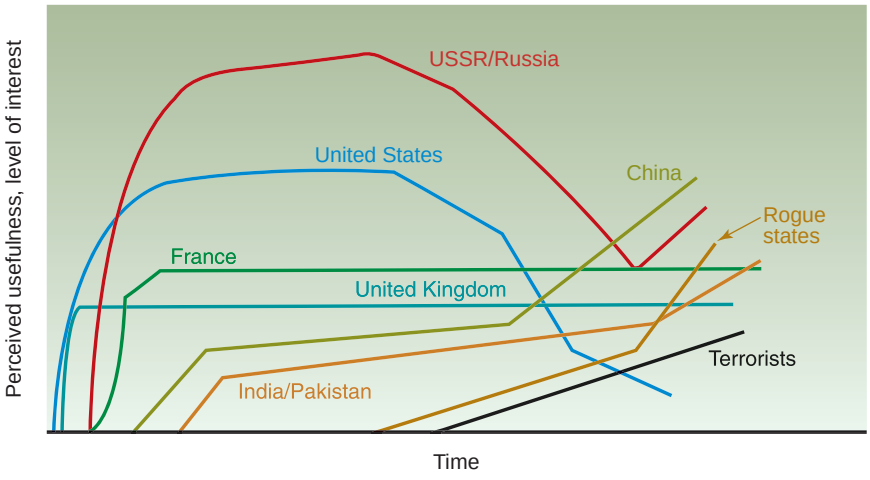
Former Secretary of Defense William J. Perry requested the verification study, which was conducted by CGSR and Stanford University's Center for International Security and Cooperation. Michael May, a former Livermore director, led the Stanford effort, and Lehman headed the Laboratory effort. Robert Schock, a CGSR senior fellow, says the report's bottom line is that the agreement with North Korea is verifiable, provided North Korea reveals the details of its weapons program.

Not only was this workshop timely, but it also got the attention of Congress and the current administration, helping them to understand the issues involved in verifying the 1994 agreement and to seek ways to speed up the verification process.

In January 2000, CGSR, together with the Institute for Strategic Studies in London, sponsored a conference titled "International Security Aspects of the Year 2000 Issue: Preliminary Assessments of What Really Happened and Lessons to Be Learned." The workshop was held at Livermore with people in London participating via videoconferencing. Attendees came from throughout the world.

In December 2000, the Center sponsored three days of discussion under the title "Beyond Moore's Law: Opportunities and Threats from Future, Ubiquitous High-Performance Computing." Representatives included personnel from the top U.S. computing and semiconductor companies, Department of Defense agencies, the Federal Bureau of Investigation, the Department of Energy, the National Security Agency, and other institutions.

CGSR and the Office of Engineering and Technology at the Federal Communications Commission (FCC) cosponsored the conference "Telecommunications Network Security and Reliability in the 21st Century" last October at FCC headquarters in Washington, D.C. Olivia Bosch, a CGSR fellow from the United Kingdom, led an effort by government, industry, and academic leaders to address major issues resulting from the rapid evolution of electronic communications technologies.



The perceived usefulness of nuclear weapons has changed significantly in recent years. It has declined for the U.S., but it has climbed sharply for other nations and terrorist groups.

In 1999, missile proliferation specialists convened for two days of discussion hosted by CGSR on the subject of "Missile Proliferation in a World of Rapidly Advancing Technology." The conference was, in part, a follow-up to the Congressionally mandated Commission to Assess the Ballistic Missile Threat to the United States, which released its report in July 1998. Donald Rumsfeld, now Secretary of Defense, headed the commission, which concluded that efforts by hostile or potentially hostile countries to acquire ballistic missiles pose a growing and largely underestimated threat to the U.S. and its allies.

Also in 1999, the Center held a workshop on "Proliferation-Resistant Nuclear Power Systems," at which a group of 90 international experts addressed the major questions and challenges surrounding the relationship between future nuclear power and the proliferation of nuclear materials for weapons and other means of nuclear terrorism. The focus was on the role that new technologies can play in enhancing the proliferation-resistance of civilian nuclear power systems. This workshop led directly to a Department of Energy study to recommend research and development in proliferation-resistance technology.

The report from this workshop was published in March 2000. The following June, Harold Feiveson of Princeton University cited the report in a conference paper at Stanford University, describing it as "an elegant overview of many of the proliferation-resistance concepts."

CGSR Influence Is Long Term

The effects and influence of CGSR projects and workshops are difficult to determine because they are frequently subtle and long term. For Vergino, the value of CGSR workshops lies more in the process than in the product. "The sessions are an enriching experience for both scientists and policymakers," says Vergino. "Because scientists don't focus

Possible Future Threats to the Nation

Major threats to the nation's security were identified and ranked by leading scientists and policymakers as part of "After Globalization" workshops. In order of highest risk (probability of occurrence times severity of consequences), the threats are assessed as follows:

Nuclear weapons in a terrorist attack. The danger that terrorists might use a crudely fashioned, purchased, or stolen nuclear weapon to attack a city has increased in recent years because of the proliferation of nuclear weapons and materials and the international increase in nuclear technology. At the same time, the rise of nuclear-enabling technologies, such as computing, robotics, and remote control, increase the probability that a terrorist could acquire and use a nuclear weapon. Such extreme terrorism might be viewed as useful to a number of organizations, especially those with nothing to lose. Attribution of such an attack could be difficult if the sponsoring group does not claim responsibility.

Natural and manufactured diseases. This threat has the potential for considerable misery and loss of life. Diseases considered to be eliminated or under control still exist in biological storage, persist in relatively isolated populations, or are reemerging in drug-resistant forms. Much of the once-immunized population is again vulnerable to smallpox, for example, and to antibiotic-resistant tuberculosis. In addition, new diseases are emerging, and biotechnology provides the means to modify and combine disease elements to tailor their effects. Some consider the means to design, manufacture, and disperse microbes for a biological attack relatively simple yet difficult to detect, and the knowledge of how to accomplish these ends is widespread. (See *S&TR*, May 2000, pp. 4–12.)

Limited regional nuclear war. Emerging nations cannot afford to deploy sophisticated systems of conventional arms. Nuclear weapons give a nation immediate dominance over its adversaries or at least "nuclear peerage," enormous deterrent capability, and significant stature among world powers. Nations possessing nuclear capabilities include Israel, India, Pakistan, Iraq, Iran, and North Korea, and others could acquire weapons over the next two decades. A situation could result in which one nation uses a nuclear weapon out of desperation, for vengeance, or to disable electrical devices. Such use of nuclear weapons might motivate other nations to acquire and use them, and the risk of nuclear conflict would be increased.

Major nuclear war. While the threat of global nuclear war has receded, large arsenals and delivery capabilities still exist. This threat ranks high not because of any current tension but because of the potential for catastrophe. Experts say that the current global situation is not like the East–West standoff that marked the Cold War. Rather, it resembles the multifaceted national relations that preceded World War I. Currently, several emerging nuclear nations, many of which harbor intense animosities, are involved in a complex web of alliances with each other and with established nuclear powers.

Human control of future biological forms. The threat from the malicious applications of biotechnology is widely discussed. However, new biological forms, developed out of the best of intentions, could have unexpected consequences. Through evolution, today's life forms have established complex interrelationships such that species are in equilibrium with their environments. Most future biological creations will serve specific purposes such as manufacturing medicines and organs for human use or seeds containing transplanted genes. These new biological forms will not be ecologically tested, and the dangers of unintended ecological and human disruptions could be significant.

Blunting of U.S. force projection. An array of new air defense and air combat technologies could diminish U.S. air dominance and capability and necessitate a new generation of strike and countermeasure technologies. The emerging technologies include sensors to defeat aircraft infrared countermeasures (for example, decoys that fool heat-seeking missiles), dome optics to give antiaircraft missiles greater speed and range, radar systems to lessen the effectiveness of stealth aircraft and antiradar missiles, visible-light sensors to lessen the effectiveness of cruise missiles, and improved infrared systems to increase the effectiveness of night operations. Also, stealth technology will likely become available for adversaries' aircraft, missiles, and ships, which will require greater protection for U.S. forces.

Gained and lost control of nature. Understanding weather, ocean currents, and geologic systems through computer simulation for long-term prediction—and possibly control—could generate new global threats. For example, one nation might understand how to generate a tsunami (giant tidal wave) by destroying an undersea continental shelf. In addition, human activities that add greenhouse gases are changing the weather in ways we cannot control. The effects of these changes, both beneficial and harmful, are quite varied. Their distribution among regions and nations, when better understood, is certain to be a source of international antagonism.

In addition to the seven major threats listed above, two others were cited:

Information attacks. U.S. computer systems are vulnerable in varying degrees, from simple intrusion and denial of services to coordinated, sophisticated attacks on financial activities, infrastructure, and military information. Last year, such attacks disabled Internet services and cost considerable amounts of money. These techniques could be used to design, control, and execute the listed threats, as well as to disrupt responses. However, at the Center for Global Security Research workshops discussed in the article, participants argued that defenses against information operations would evolve as needed and that such attacks by themselves would not destabilize the U.S. government, economy, or military.

Asymmetry. U.S. military dominance over other nations is an example of asymmetry. It is unlikely during the next two decades that any adversary will defeat us in conventional conflict. However, it is possible some group or nation, using a crude or breakthrough technology, could achieve asymmetry to its advantage. Participants agreed that such attacks would not seriously threaten the survival of the U.S. military or government but that determined adversaries could cause significant localized harm.

on policy, it's important for them to hear where policy is going and what its limitations are. At the same time, it's important for policymakers to hear where science is heading."

The center plans to examine the effects of new technologies in different ways. One effort under consideration is a series of workshops devoted to biotechnology and national security. In that light, a new fellow, a molecular biologist, will be joining CGSR. As with all CGSR projects, the overriding goal is not to achieve consensus but to clarify what U.S. national security experts know and what they need to learn about possible threats in the coming decades.

—Arnie Heller

Key Words: biological warfare, Center for Global Security Research (CGSR), globalization, nonproliferation, nuclear weapons, terrorism.

For further information contact Eileen Vergino (925) 422-3907 (vergino1@llnl.gov).

The reports on the "After Globalization" and "North Korea and Nuclear Power" workshops can be found on the Web at cgsr.llnl.gov/global/global.html. For more information on the Center for Global Security Research and its work, see cgsr.llnl.gov/.

Above, a conference on lessons from the Y2K experience linked participants at Livermore and in London by videoconferencing. Workshops sponsored by Livermore's Center for Global Security Research often bring together participants from nations that are not on the friendliest of terms. At right, two experts from India and Pakistan confer at last year's Y2K workshop.

About the Scientist

EILEEN VERGINO is deputy director of Livermore's Center for Global Security Research (CGSR). She is responsible for helping to plan and implement CGSR studies, in particular those that examine how technology can enhance international security. She has primary responsibility for developing and implementing new collaborations between CGSR and academia, industry, and international government and nongovernment organizations and thus link Livermore science and technology expertise with outside policy expertise. She also has primary responsibility for community development activities with the city of Snezhinsk, Russia, as part of the Nuclear Cities Initiative. She serves on the Department of Energy's Community Development Task Force and was instrumental in establishing the sister-city relationship between Snezhinsk and Livermore.

Vergino, who has a B.S. in geophysics from the Massachusetts Institute of Technology, worked for over 16 years as a seismologist in Livermore's Treaty Verification Program on seismic yield estimation and discrimination studies. She is also the former director of Education Programs at Livermore and was responsible for creating and implementing regional and national education outreach programs for students and teachers from elementary school through graduate degree programs.